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Correlation of intravascular ultrasound and computed tomography scan measurements for placement of intravascular ultrasound-guided inferior vena cava filters

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Objective: **The single puncture intravascular ultrasound (IVUS)-guided bedside placement of inferior vena cava (IVC) filters has been shown to be an effective technique. The major disadvantage of this procedure is a steep learning curve that can lead to an increased risk of filter malposition. In an effort to increase the safety and efficacy of IVUS-guided bedside IVC filter placement, we proposed that preoperative planning could reduce the incidence of IVUS-guided filter malpositions. As a first step, we examined the correlation between preoperative abdominal computed tomography (CT) scan measurements and intraprocedural IVUS derived measurements of vena cava anatomy and its surrounding structures. As a second step, we attempted to determine the safety of this protocol by assessing the incidence of malposition.**

Methods: **A retrospective review of prospectively collected data was performed on all patients receiving bedside IVUS-guided filters from July 1, 2010 to August 31, 2011. Measurements of the IVC length from the atrial-IVC junction to the midportion of the crossing right renal artery, the lowest renal vein, and iliac vein confluence were obtained prior to IVC filter placement by both CT-based measurement, as well as intraprocedural IVUS pullback lengths. Regression analysis (significant for $P < .05$) was used to determine the correlation between these imaging modalities.**

Results: **Forty-six patients had adequate CT scans available to perform the analysis and were candidates for bedside IVUS-guided IVC filter placement. All IVUS-guided filters were placed using a single puncture technique with the Cook Celect Filter. This study found there was a close correlation between IVUS and CT derived measurements of the right atrium to right renal artery distance, lowest renal vein distance, and iliac confluence distance. In addition, we found that the IVUS distances from the atrial-IVC junction to the right renal artery and lowest renal vein were statistically similar. Nine patients had 10 vascular anatomic variations, all identified by both IVUS and CT. There were no complications or malpositions of IVC filters using this protocol.**

Conclusions: **These data suggest that IVUS pullback measurements from the right atrium used in combination with preprocedure CT derived measurements of the distance from the right atrium to the lowest renal vein and iliac vein confluence provide an accurate roadmap for the placement of bedside IVC filters under IVUS guidance. We provide a method for organizing this information in a preplanning document to aid this procedure. We suggest this easily employed technique be more fully utilized to help decrease the incidence of malpositioned filters using single puncture IVUS guidance. (J Vasc Surg 2014;59:1066-72.)**

The placement of inferior vena cava (IVC) filters has traditionally been performed using fluoroscopic guidance; however, over the course of the past decade, the use of ultrasound guidance (both intravascular ultrasound [IVUS] and transabdominal) for the placement of IVC filters has increased.[1-23] One of the most significant advantages of using ultrasound technology for guidance of filter placement is the ability to avoid the transfer of critically ill patients (spinal cord injuries, severe head injuries, patients on high ventilator settings) by performing bedside placement.[24,25] Additional advantages include the avoidance of contrast, radiation, cost effectiveness, and the convenience of not needing an operating room.[20,26,27] The major disadvantage of bedside placement and the leading reason for this technique not being universally adopted is the relative high incidence of malposition (average, 2%-3%, however, as high as 8%).[12,18-20] This is especially true for practitioners with little experience in performing the technique, as the learning curve is steep. Malposition most often occurs as a result of the misidentification of normal anatomy (confluence of the external and internal iliac veins being misinterpreted as the confluence

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of the common iliac veins, common iliac artery misidentified as the right renal artery). In addition, filter malposition may result from the lack of recognition of venous anomalies (left-sided IVC, duplicated IVC, accessory renal veins, and circumaortic renal vein), which may confuse the anatomy for the operator.[8,10]

To decrease the incidence of malposition, we determined that we must find a way to more accurately identify landmarks, prevent the misinterpretation of normal anatomy, and identify venous anomalies that may contraindicate the placement of IVC filters under ultrasound guidance (duplicated IVC, left-sided IVC). The majority of the patients at our institution receiving IVC filters were trauma patients, and we realized that almost all of these patients had computed tomography (CT) scans as a part of their trauma work-up. In this investigation, we attempted to determine if we could correlate measurements of anatomic landmarks obtained from these CT scans to those obtained with IVUS to increase the accuracy of placement.

METHODS

A retrospective review of prospectively collected data was performed on all patients receiving bedside IVUS-guided filters from July 1, 2010 to August 31, 2011. Institutional review board approval was obtained for this investigation. Prior to performing the procedure, the patient's CT scan was evaluated for the presence of venous anomalies, size of the inferior vena cava, and for the location of the above landmarks. These landmarks were then used to identify a landing zone for the IVC filter between the lowest renal vein and the iliac venous confluence of at least 6 cm in length (length of the IVC filter prior to deployment) (Fig 1).

CT scan measurements. The atrial-IVC junction was identified as the image below the heart where the IVC was clearly a separate structure (completely circumscribed by venous wall) from the right atrium (Video I, online only). The location of the right renal artery was defined as the image where the midpoint of the lumen of the artery passed directly behind the IVC (Video II, online only). The locations of the right and left renal veins were defined as the image where the midpoint of the lumen of the renal vein entered the IVC (Videos III and IV, online only). The location of the iliac vein confluence was defined as the image where both common iliac veins were clearly visualized as separate structures distal to the IVC (Video V, online only). Distances were then calculated from the atrial-IVC junction to the right renal artery, lowest renal vein and iliac vein confluence. The distances were then transferred to an IVC filter planning sheet (Fig 1) and displayed for reference during the procedure.

IVUS measurement protocol. The atrial-IVC junction was identified as the point below the heart where the IVC was clearly a separate structure (completely circumscribed by venous wall) from the right atrium. The locations of the left and right renal veins were defined as the point where the midpoint of the lumen of the renal vein entered the IVC. The location of the right renal artery was defined as the image where the midpoint of the lumen of the artery passed directly behind the IVC. The location of the iliac vein confluence was defined as the point where both common iliac veins were clearly visualized as separate structures distal to the IVC. The probe was then placed at the level of the atrial-IVC junction and at the distal hub of the catheter, a Glow'N Tell Tape (LaMaitre Vascular, Inc, Burlington, Mass) was affixed to the drape and deployed along the line of the guidewire distally overtop of the patient's thigh. The IVUS probe was then pulled back over wire, and at the location of each landmark, a mark was made on the Glow'N Tell Tape. Distances were then calculated from the atrial-IVC junction to the right renal artery, lowest renal vein, and iliac vein confluence. The distances were then correlated with those obtained from the CT scan.

IVUS-guided IVC Filter placement. The single puncture pullback technique with IVUS guidance originally described by Jacobs et al utilizes the 8.2F IVUS probe and 8.5F Cook Celect Filter system (Cook Medical Inc, Bloomington, Ind).[15] We employed a two-person technique where one person was responsible for the device and the other for maintaining the position of the sheath. The IVUS probe is placed in the right atrium and pulled back over wire to identify the appropriate landing zone for the filter below the lowest renal vein and above the iliac venous confluence. The renal veins are identified by correlating them with the right renal artery as it passed behind the IVC. The iliac confluence is identified on pullback as the point where the iliac veins converge to form the IVC. Once these landmarks are identified, the IVUS probe is placed just below the lowest renal vein. The IVUS is pinned at that level, and the sheath is advanced over the IVUS probe to the point where the tip of the probe is just outside of the sheath. In general, there is a characteristic change in brightness as the probe exits the sheath. This ensures that the tip of the sheath is below the lowest renal vein. The sheath is pinned at the skin by one of the two operators and the IVUS probe and wire are removed by the second operator. It is critically important that the operator pinning the sheath at the skin does not move the sheath, as this would result in malposition of the device. The IVC filter is then advanced into the sheath and deployed according to the instructions for use and placement is confirmed with IVUS (Video VI, online only).

Statistical analysis. Regression analysis was used to determine if there was correlation between measurements. Comparison of means (all data normally distributed) was performed with use of paired Student's *t*-test (significant for $P < .005$). Data analysis was performed with IBM SPSS Statistics v. 19 (Armonk, NY).

RESULTS

There were 54 patients with IVC filters placed by bedside technique during the study period. During this period, 47 patients had adequate CT scans available to perform the preoperative analysis. Of these 47 patients, one patient had a left-sided IVC whom we excluded

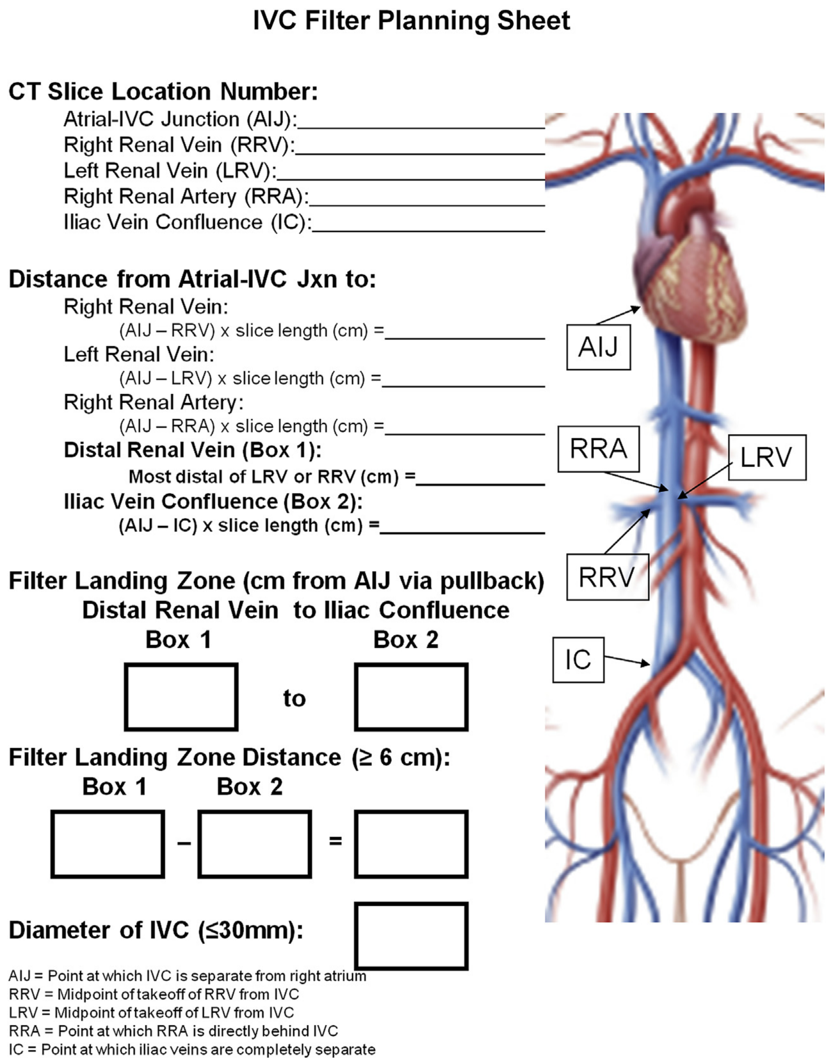

Fig 1. Bedside intravascular ultrasound (IVUS)-guided inferior vena cava (*IVC*) filter planning document. *AIJ,* Atrial IVC junction; *IC,* iliac confluence; *LRV,* lowest renal vein; *RRV,* right renal vein.

from bedside placement, and he underwent successful filter placement under fluoroscopic guidance. There were 46 patients who received bedside IVC filter placement with IVUS guidance under this protocol. Demographics are listed in Table I. The majority of patients were middle-aged, male, and had their filter placed because of the relative indication of trauma with a contraindication to anticoagulation. Twenty-two percent of patients had an arterial or venous anatomic variation, the majority of those being venous. All vascular variations found on CT scan were identified with IVUS. Distances from the atrial-IVC junction and statistical analyses comparing IVUS and CT measurements are listed in Table II. The average landing zone length between the lowest renal vein and iliac venous confluence was approximately 12 cm. In our study population on IVUS evaluation, the most distal of the lowest renal veins was 16.0 cm and the most proximal of the iliac confluences was 19.6 cm from the atrial-IVC junction, respectively. Regression analysis demonstrated excellent correlation between CT and IVUS derived distances from the atrial-IVC junction to the right renal artery, lowest renal vein, iliac confluence, and overall to all landmarks (R^2 = 0.890, 0.841, 0.818, 0.976, respectively) (Fig 2). We found that there was a statistical correlation between the location of the right renal artery and lowest renal vein on IVUS and that there was no statistically significant difference in paired Samples test between the distances from the atrial-IVC junction to these structures suggesting that either the lowest renal vein or the right renal artery (if the lowest renal vein was not visualized) may be used as an appropriate landmark for filter deployment (Table III, Fig 2).

The location of the right renal artery was routinely at the level of the lowest renal vein, and in no patients was outside of the margin of error permitted for deployment of the barbs below the level of the lowest renal vein (6 cm margin of error, or the length from the tip of the

Table I. Demographics, indications, and imaging findings

Median age, years	47
Male	81%
Indication	
Trauma with contraindication to anticoagulation	91%
Venous thromboembolism with contraindication to anticoagulation	9%
Vascular variations	22%
Venous	15%
Accessory renal vein	7%
Circumaortic renal vein	4%
Retroaortic renal vein	2%
Renal vein ligation in trauma	2%
Arterial	7%
Accessory right renal artery	5%
Low right renal artery	2%

Table II. Correlation of intravascular ultrasound (*IVUS*) vs computed tomography (*CT*) distance from atrial-inferior vena cava (IVC) junction (cm) to vascular landmarks

	CT	*IVUS*	P	R^2
Right renal artery	12.6	12.7	<.001	0.890
Lowest renal vein	12.4	12.7	<.001	0.841
Iliac venous confluence	24.9	24.7	<.001	0.818

filter to the level of the barbs). The greatest outlier had a renal artery 5 cm proximal to the lowest renal vein (Fig 2). In this patient, the lowest renal vein was a duplicated diminutive renal vein with the main renal vein being at the level of the right renal artery. No other distances between the renal artery and lowest renal vein were greater than 3 cm, well within the margin of error. If the right renal artery were used as a landmark for deployment of the filter, there would have been no malpositions within our patient population.

In addition, there were no complications, malpositions, or procedure abandonments under this protocol. There are no statistically significant data correlating IVUS vs CT IVC diameter, as most patients were trauma patients in a hypovolemic state upon presentation/initial CT scan with partially collapsed IVCs.

DISCUSSION

In this study, we found that vena cava anatomy determined by preprocedural CT scans highly correlates with intraprocedural interpretation of vena cava anatomy using IVUS. The major disadvantage of the use of IVUS guidance for the placement of IVC filters is the relatively high incidence of filter malposition early in the practitioner's experience. This has been found to be as high as 8%.[8,18-20] This is largely due to misinterpretation of venous anatomy seen in cross-sectional detail using IVUS. According to the instructions for use for the Volcano IVUS catheter (Volcano Corp, San Diego, Calif), the procedure is to be performed with the aid of fluoroscopic guidance to avoid misinterpretation of anatomy and catheter position. Misinterpretation of IVUS imaging may occur since the catheter may rotate freely during the procedure, thereby showing that structures that are known to be anterior are displayed posteriorly, laterally, or medially. A recent study by Kassavin et al suggests that the average number of cases to become comfortable with this new imaging technique is around 20 cases.[20] Contrast venography has been compared with IVUS for locating the appropriate landing zone for IVC filter placement; however, taking the patient to the operating room (OR) to confirm IVUS location by venography defeats the purpose and negates the benefits of performing these procedures at the bedside.[4] In addition, previous studies have reported specifically on the cost-effectiveness of bedside IVUS-guided filter placement compared with fluoroscopically guided filters. They have determined that the placement of bedside IVUS-guided filters is cost-effective compared with the use of fluoroscopy.[26,27]

A possible source of bias within this protocol is that the measurements based upon the preprocedural CT scan were not blinded from the IVUS operator. The initial measurements obtained by IVUS were not compared with CT until after all measurements were obtained; however, as a matter of safety for this protocol they were compared prior to placement of the IVC filter. Any disagreement in measurements was uniformly due to the level of identification of the atrial-IVC junction (either being identified as higher or lower on CT than on IVUS). All distances between other landmarks (ie, right renal artery to lowest renal vein, right renal artery to iliac venous confluence, etc.) were consistent between imaging modalities.

In comparison to other methods of IVUS-guided IVC filter deployment there are significant benefits to the use of this protocol. In comparison to the single puncture technique without preoperative landmark identification, this protocol allows for the identification of aberrant anatomy that may necessitate change in procedure (duplicated IVC) or procedure abandonment (left-sided IVC).

The use of the double puncture technique has been advocated to reduce the incidence of malpositions by accessing one common femoral vein with the device and the contralateral common femoral vein with IVUS. This method requires dual access potentially increasing the incidence of access site complications. In addition, the double puncture method has no ability to identify or account for which venous anomalies may lead to malpositions. It also does not allow for preoperative assessment of the venous system that may identify anatomy prohibitive for IVUS-guided IVC filter placement (left-sided IVC), leading to increased costs associated with procedure abandonment.

The key to performing this procedure safely is the identification of landmarks that are often subtle. It is known that venous volume varies according to the patient's hydration status. As such, the vena cava diameter often varies, being described as anisotropic and venous tributaries may

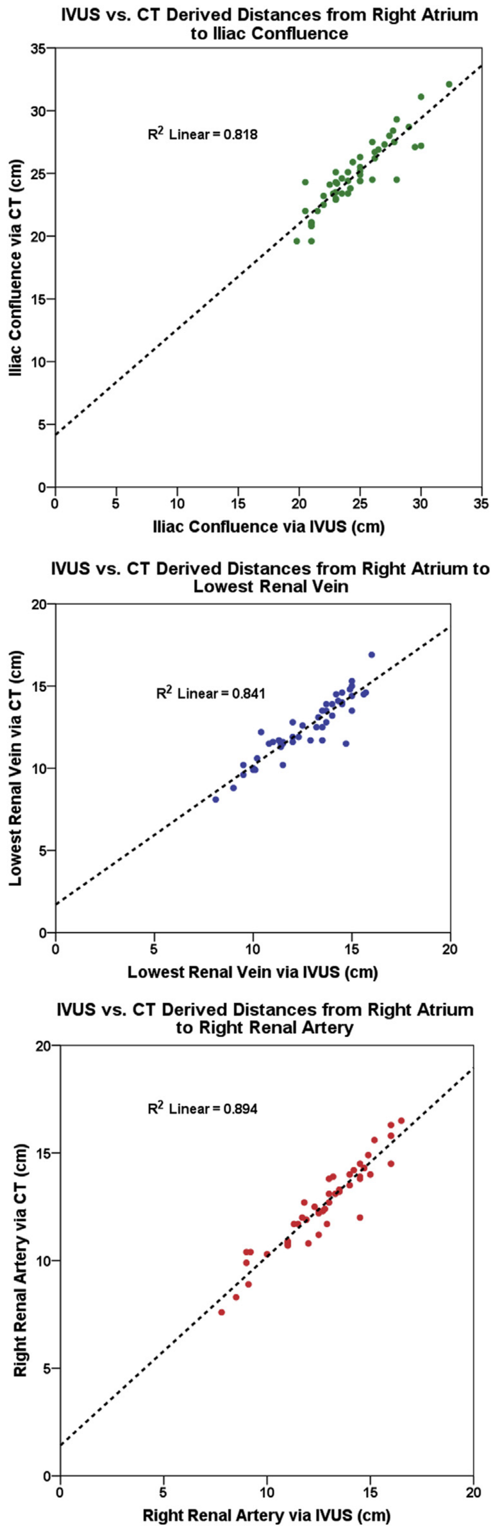

Fig 2. Graphic representation of correlation of intravascular ultrasound (*IVUS*)-guided vena cava measurements with preoperative computed tomography (*CT*) angiography determined vena cava measurements from right atrium to the lowest renal vein, right renal artery, and iliac confluence using logistic regression.

Table III. Correlation of intravascular ultrasound (IVUS) distance from atrial-inferior vena cava (IVC) junction (cm) lowest renal vein (*LRV*) and right renal artery (*RRA*)

	RRA	*LRV*	P	R^2
Distance	12.7	12.7	<.001	0.569

appear slit-like instead of oval.[28] To compensate for this, we use the right atrium as the initial landmark that must be identified, as it is the only landmark in the IVUS environment that is universally identifiable. In the right atrium, the IVUS displays a large cavity that is pulsatile. No other site in venous anatomy will have these characteristics. However, despite this universal landmark, it is still relatively easy to miss the renal veins and right renal artery with a rapid pullback. If this occurs, then the operator is likely to misinterpret the iliac confluence as the takeoff of a renal vein and the iliac artery as the right renal artery. This will result in the deployment of the filter in the common iliac vein. For this reason, it is critical to have a roadmap of the relative locations of the anatomic landmarks to provide a safe landing zone for the filter prior to performing the procedure.

This protocol takes advantage of CT scans already performed on patients to provide a roadmap for the placement of filters under IVUS guidance. In this protocol, we were able to demonstrate a high degree of correlation between the roadmap provided by the preprocedural CT scan and the measurements obtained by interprocedural IVUS. It was not uncommon during the performance of these filter placements for there to be initial misinterpretation of normal anatomy, even by the most experienced of operators. However, as a result of the roadmap provided by the CT scan, operators were uniformly able to correctly identify landmarks and successfully perform the procedures.

The majority of these procedures were prophylactic and performed for the relative indication of trauma with a contraindication to anticoagulation (which has been shown subsequently to not be an appropriate indication in most patients, as prophylactic low-molecular-weight heparin has been shown to be safe at 72 hours postinjury in most patients). Nine percent of the patients had a venous thromboembolism with contraindication to anticoagulation and a CT scan at some point in the past due to pre-existing medical conditions (malignancy, trauma, preoperative planning for other procedures). There were seven patients who did not have axial imaging in whom IVUS-guided bedside filters were placed during the study period. These were only placed in patients with a venous thromboembolism and contraindication to anticoagulation in which transport to the OR for fluoroscopic guidance outweighed the risk of malposition due to patient extremis. We do not recommend obtaining a CT scan for the sole purpose of bedside placement of IVC filter as this would negate the benefit obtained by not transporting the patient to the OR. The cost effectiveness of this bedside procedure compared to fluoroscopic guidance in the OR was not evaluated.

Devices currently in development that combine both an IVC filter and IVUS in a single device have the potential to decrease the incidence of malpositions by allowing for the landmarks to be visualized during deployment similar to the double puncture technique. They will also potentially decrease the incidence of access site complications in comparison to the double puncture technique as they will be performed through a single access site. However, these combined devices will not prevent the misidentification of normal anatomy or allow for the identification of aberrant anatomy that may impact placement location (duplicated IVC, left-sided IVC, duplicated right renal artery or right veins).

The addition of inked markers on the Volcano Visions PV 0.035 Digital IVUS catheter (Volcano Corp) (not available at the time of this protocol) has obviated the need for the use of the Glow'N Tell Tape and may potentially make the measurement of landmarks more accurate.

In this study we were able to show that it is feasible to use preoperative CT scans as a roadmap for later IVC filter placement by IVUS guidance. Preoperative CT scan also assisted in the identification of aberrant anatomy in 20% of the patients in this protocol, some of which may have led to procedure abandonment or malposition (duplicated right renal arteries, duplicated renal veins, left-sided IVC).

CONCLUSIONS

IVUS pullback measurements from the right atrium used in combination with preprocedural CT derived measurements of the distance from the right atrium to the lowest renal vein and iliac vein confluence provide an accurate roadmap for the placement of bedside IVC filters under IVUS guidance. We provide a method for organizing this information in a preplanning document to aid this procedure. We suggest this easily employed technique be more fully utilized to help decrease the incidence of malpositioned filters using single puncture IVUS guidance.

AUTHOR CONTRIBUTIONS

Conception and design: DG, SH, DF
Analysis and interpretation: DG, SH, DF
Data collection: DG, SH, DF
Writing the article: DG, SH
Critical revision of the article: DG, SH, AD, JE, AC
Final approval of the article: DG
Statistical analysis: DG, SH
Obtained funding: DG
Overall responsibility: DG

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